Safety of the lateral trauma position in cervical spine injuries: a cadaver model study

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Conflicts of interest
PKH developed the concept of the LTP, but has gained no economic benefit from that work. The remaining authors declare no economic or other conflicts of interest.

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Background: Endotracheal intubation is not always an option for unconscious trauma patients. Prehospital personnel are then faced with the dilemma of maintaining an adequate airway without risking deleterious movement of a potentially unstable cervical spine. To address these two concerns various alternatives to the classical recovery position have been developed. This study aims to determine the amount of motion induced by the recovery position, two versions of the HAINES (High Arm IN Endangered Spine) position, and the novel lateral trauma position (LTP).
Method: We surgically created global cervical instability between the C5 and C6 vertebrae in five fresh cadavers. We measured the rotational and translational (linear) range of motion during the different maneuvers using an electromagnetic tracking device and compared the results using a general linear mixed model (GLMM) for regression.
Results: In the recovery position, the range of motion for lateral bending was 11.9°. While both HAINES positions caused a similar range of motion, the motion caused by the LTP was 2.6° less ($P = 0.037$). The linear axial range of motion in the recovery position was 13.0 mm. In comparison, the HAINES 1 and 2 positions showed significantly less motion (−5.8 and −4.6 mm, respectively), while the LTP did not (−4.0 mm, $P = 0.067$).
Conclusion: Our results indicate that in unconscious trauma patients, the LTP or one of the two HAINES techniques is preferable to the standard recovery position in cases of an unstable cervical spine injury.

Editorial comment: what this article tells us
In this cadaver study, several different positions were compared to assess the range of motion of an unstable cervical spine. The traditional recovery position was associated with significantly greater range of motion than the other positions, such as the 'High Arm IN Endangered Spine' and the novel lateral trauma position.

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Prehospital care of patients with severe traumatic brain injury (TBI) includes both airway[1] and cervical spine (C-spine) protection.[2] Airway patency is essential to prevent hypoxia, which can worsen the effects of a TBI.[3–7] To prevent hypoxia and/or hypoventilation, the airway must be protected.[8–10] While drug-assisted endotracheal intubation (ETI) is regarded as the gold standard,[11] it may not be available before a TBI progresses to irreversible pathology or patient death. In addition, in many emergency medical service (EMS) systems throughout the world, care providers are not trained in drug-assisted ETI and have to rely on more basic measures.

A recent systematic review and meta-analysis supported the existing belief that the supine position is associated with the loss of airway patency in unconscious patients.[12] International resuscitation guidelines have therefore suggested that the recovery position (Fig. 1) should be used to maintain airway patency in unconscious patients who are breathing spontaneously.[13,14] However, it is unclear whether the recovery position provides adequate c-spine protection. To improve the spinal protective aspect of the recovery position, the HAINES method (High Arm IN Endangered Spine) and a modification thereof have been recommended for basic providers (Figs. 2 and 3).[15,16] An alternative method, the lateral trauma position (LTP; Fig. 4) is also used.[17] Unlike the other three techniques, the LTP approach is targeted at EMS personnel and requires two rescuers and the use of a cervical collar.

A previous study reported little difference between the standard recovery position and the HAINES position[18] in terms of C-spine protec-

Fig. 1. The recovery position
The recovery position recommended by the European Resuscitation Council, among others. Written informed consent was obtained from the models (healthy volunteers) for publication of the accompanying images.

Fig. 2. The HAINES position
The HAINES position as John Haines proposed it in 1996, with both legs flexed (HAINES 2).

Fig. 3. The modified HAINES position
A modification of the position originally proposed by John Haines, with one leg flexed (HAINES 1).

Fig. 4. The lateral trauma position
The lateral trauma position, which involves two rescuers during turning and a semi-rigid cervical collar.

tion. Understanding how much motion the LTP and other positions create in an unstable spine is important to refine emergency management practices so that they minimize the potential for a catastrophic secondary injury. The purpose of this study was to determine the amount of motion created by the recovery position, two versions of the HAINES method and the new LTP in a cadaver model with a surgically created unstable cervical spine. The hypothesis was that under these conditions, the LTP would reduce spinal motion compared with the other three methods.

Methods

The primary endpoints for the study were angular motion in three planes, and linear motion along three axes (Fig. 5). These were measured as ranges of motion (ROM; maximum minus minimum values) for all six variables.

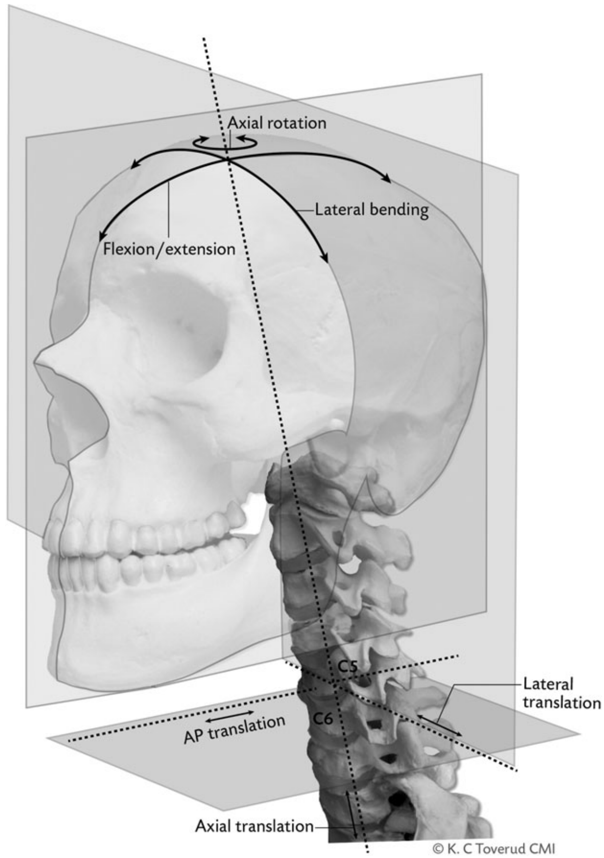

Fig. 5. Planes and axes of recorded motion
The figure shows the planes of the angular motion and the axes of the linear motion (translation) that were recorded in the study using an electromagnetic tracking device. © Kari C. Toverud, CMI.

Ethics committees approval

The study was conducted under the auspices and review of the Bay Pines VA Healthcare System Research and Development Committee, which determined that the study did not require IRB review because it did not involve human subjects (protocol number 2889). The cadavers were de-identified to all of the investigators, and therefore, the Norwegian Regional Ethical Committee exempted the study from registration in Norway (reference number 2013/919).

Cadaver model

We applied a cadaveric model that was previously developed by a US research group.[19–24] For this study, five fresh cadavers were used. First, the passive range of motion was tested to establish a baseline for flexion, extension, rotation, and lateral bending. A spinal surgeon (GRR) then created cervical instability between the C5 and C6 vertebrae (C5-C6) to simulate a segmental lesion that would result in global instability. Excising the supraspinous and intraspinous ligaments, ligament flavum, spinal cord, facet capsules, and longitudinal ligaments (anterior and posterior), as well as the intervertebral disks, created global instability. The same surgeon performed all of the surgical procedures.

Experimental approach

After the cervical spine lesion was created, the five cadavers were positioned to assess the amount of motion in the cervical spine lesion induced by the four techniques: the standard recovery position,[25] the HAINES position (High Arm IN Endangered Spine),[15] a modification of the HAINES position with only one leg flexed, and the LTP.

Recovery position

The cadaver was rolled onto its side with the nearside arm positioned at 90° to the torso. The cadaver's far side arm was placed across the body and under the cheek. The far side leg was flexed in a 90 : 90° position with the foot flat on the floor before the cadaver was rolled onto its side. The cadaver's flexed leg was pulled over while the head was protected by the hand under the cheek (Fig. 1).

HAINES position (two legs flexed; HAINES 2)

The cadaver was turned on its side with the nearest arm fully abducted and both legs bent at the knees. After the cadaver was positioned, the head was stabilized on the fully abducted arm (Fig. 2).

Modification of HAINES position (one leg flexed; HAINES 1)

This technique is identical to HAINES 2 except that only the far side knee was bent in a 90 : 90° position prior to turning the cadaver (Fig. 3).

Lateral trauma position (LTP)

One person immobilized the cadaver's head and neck manually while a second person placed a standard semi-rigid cervical collar on the patient's neck. The second person then angled the cadaver's far side knee, leaving the nearest leg straight, and extending the nearest arm 90° to the torso. The second person gripped the far side shoulder and hip, and the cadaver was logrolled into the LTP while the first person coordinated the maneuver and maintained manual in-line stabilization. Padding was placed under the head to allow neutral alignment of the spine (Fig. 4).

To minimize inter-clinician variability, the same two skilled providers (MBH and LW) were used throughout the study. Each provider consistently performed the same tasks throughout all of the testing sessions. The techniques were repeated three times on each cadaver. The testing order of the techniques was randomized using an online randomization program (https://www.randomizer.org/).

Cervical spine motion assessment

Angular and linear motion were measured during the execution of the four techniques using an electromagnetic tracking device (Liberty, Polhemus Inc.™, Colchester, VT), which is one of the methods deemed reliable in a review by Voss et al.[26] The device measures position and angulation of its sensors in an electromagnetic field at a frequency of 240 measurements/sec, giving continuous data on linear and angular motion between the two sensors applied. In this study, sensors were attached to the posterior aspect of the C5 and C6 vertebrae. We also placed the transmitter for the tracking system in the cadaver's chest to minimize the distance to the sensors and optimize the accuracy of the measurements. The static accuracy is 0.08 mm and 0.3° within the optimal operating range of 10–70 cm, according to the manufacturer (http://polhemus.com/_assets/img/LIBERTY_Brochure.pdf).

Measurements of rotation included flexion-extension, lateral bending and axial rotation between the C5-C6 segments. Linear motion (translation) was also measured and recorded as axial, medial-lateral, or anterior-posterior (Fig. 5).

Statistical analysis

The data collected were the ranges of motion (ROM) for all six variables. Measurements of all six dimensions were visualized using box plots. Data were then analyzed by fitting a generalized linear mixed model (GLMM), which is an extension of traditional linear regression models and allows for adjustment when correlations introduced in the dataset are due to multiple measurements of the same test subject. Rotational or linear maximum range of motion was used as the outcome in six such regression models, with the technique used being a four-level categorical explanatory variable. The recovery position was used as the reference category, as this technique does not include any measures to protect the spine and was therefore assumed to create the largest ROM. The results are presented as the estimated mean difference between the recovery position and each of the three other techniques.

To investigate whether there might be a significant learning effect when measuring the same cadaver several times, the sequence order was tested as a categorical covariate. However, repetition was not significantly associated with outcome in any of the regression models and therefore was not included in the final analyses. P-values < 0.05 were considered to be statistically significant. All analyses were performed with the R 3.1 software package (https://www.r-project.org).

Results

The box plots show that the motion induced during positioning appeared to be similar for the recovery position, the HAINES 1 and 2, and the LTP (Fig. 6). However, the regression analyses (GLMM) estimates indicated statistically significant differences between the recovery position and the three other positions (Table 1). For the recovery position, the estimate in lateral bending was 11.9°. While both HAINES positions caused a similar range of motion, the motion caused by LTP was 2.6° less ($P = 0.037$). The linear axial range of motion in the recovery position was 13.0 mm. In comparison, the HAINES 1 and 2 showed

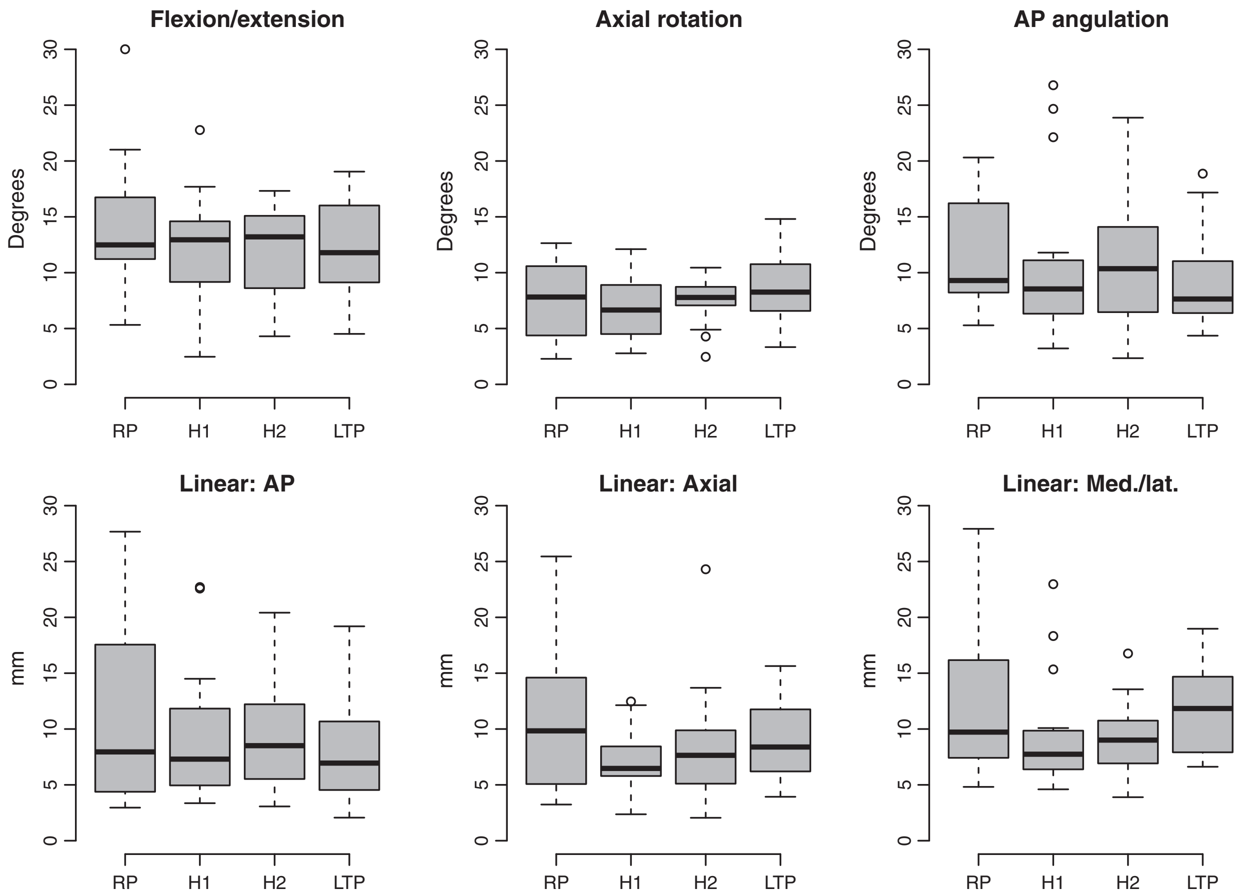

Fig. 6. Box plots of observations

The box plots depict median values (line inside the box) of the range of motion in three planes (rotational motion; degrees) and along three axes (linear motion; mm). The bottom and top of the boxes are the first and third quartiles. RP, recovery position; H1, HAINES position, with one leg flexed; H2, HAINES position, with two legs flexed; LTP, lateral trauma position.

significantly less motion (−5.8 and −4.6 mm, respectively), while the LTP did not (−4.0 mm, $P = 0.067$).

Discussion

This is the first study to investigate the motion created by the LTP in an unstable cervical spine injury model. We compared the standard recovery position to the two versions of the HAINES position and the LTP.[15–17] We found differences among the four techniques in some of the dimensions measured. Our hypothesis was that the LTP would reduce spinal motion compared with the three other methods. Our results, however, indicate that the LTP creates less motion than the recovery position, but similar motion to the HAINES 1 and 2.

International guidelines recommend placing unconscious patients in a lateral position to maintain the airway.[13,14] A recently published systematic review and meta-analysis supports this.[12] In trauma patients, the risk of additional spinal injury from being placed in a lateral position is a major concern. Our results indicate that the LTP or the HAINES 1 or 2 should be preferred to the recovery position. del Rossi et al.[18] found no differences between the recovery position and the HAINES positions. This might be due to the statistical method used. The repeated measures ANOVA used by del Rossi et al. may be overly conservative because repetition order is included as a factor. In our data, the effect of testing order was not significant and including this covariate nonetheless might potentially reduce the statistical power.

Table 1 Comparisons of spinal range of motion (angular and linear).

	Angular motion (degrees)						Linear motion (translation) (mm)					
	Flexion/extension		Axial rotation		Lateral bending		Anterior-posterior		Axial		Medial/lateral	
	Estimate (95% CI)	*P*-value	Estimate (95% CI)	*P*-value	Estimate (95% CI)	*P*-value	Estimate (95% CI)	*P*-value	Estimate (95% CI)	*P*-value	Estimate (95% CI)	*P*-value
Recovery position	14.4 (11.1, 17.7)		7.7 (5.3, 10.0)		11.9 (7.2, 16.6)		11.5 (6.6, 16.4)		13.0 (8.6, 17.3)		12.5 (8.6, 17.3)	
HAINES 1	−2.6 (−5.5, 0.4)	0.093	−0.7 (−2.2, 0.9)	0.382	−0.9 (−3.3, 1.4)	0.443	−2.2 (−5.4, 1.0)	0.180	−5.8 (−9.9, −1.6)	0.009	−2.9 (−6.0, 0.2)	0.075
HAINES 2	−2.4 (−5.3, 0.6)	0.119	−0.1 (−1.7, 1.4)	0.883	−0.6 (−3.0, 1.8)	0.627	−2.0 (−5.2, 1.2)	0.230	−4.6 (−8.8, −0.5)	0.033	−3.2 (−6.3, −0.1)	0.050
LTP	−2.2 (−5.1, 0.8)	0.154	0.9 (−0.6, 2.5)	0.247	−2.6 (−5.0, −0.2)	0.037	−2.8 (−6.0, 0.4)	0.097	−4.0 (−8.1, 0.2)	0.067	−0.9 (−4.0, 2.3)	0.586

Results of the linear regression model analysis (Generalized linear mixed models; GLMM) with rotational and linear motion estimates as outcome. Recovery position is the reference category and intercept in the GLMM. Estimates for HAINES 1, HAINES 2, and LTP are reported as positive or negative differences from recovery position estimates. HAINES 1 and 2: High Arm In Endangered Spine position, version 1 and 2. LTP, lateral trauma position; CI, Confidence interval.

It may be argued that the LTP involves two rescuers, while the three other methods require only one rescuer, possibly leading to an uneven comparison. However, this is how the four methods are applied in real life, and therefore, we think they should be tested as such. Of the four techniques, only the LTP involves a neck collar and active stabilization of the head during turning. It is interesting to observe the minimal (if any) impact that the presence of a collar has on movement in the unstable cervical spine. The LTP resembles the log roll technique, which also creates a substantial amount of movement.[20] There is a growing concern about whether stiff neck collars may contribute to raised intracranial pressure. In the future, the LTP may be amended to exclude the collar, but another version might include the use of a full-body vacuum mattress.

There are several limitations to our study. First, we cannot derive any neurological outcomes from a cadaver model. Hence, the clinical relevance of the observed differences among methods remains unknown. On the other hand, in a recently published systematic review, the authors found no evidence of harm during lateral positioning of patients.[27] However, it should be noted that no evidence found does not necessarily mean that there is no possibility of harm. Second, only a small number of C-spine injuries may display the degree of instability that we created in this cadaver study. Most real-life injuries may be unstable in one or more axes, but rarely in all directions. Our model may be seen as a worst-case scenario. Third, the statistical power of our study remains unknown. The sample size calculation of such exploratory studies is problematic. The clinical meaningful difference is unknown, as the correlation between the biomechanical variables measured in this study and the neurological outcome measures is not known. As a small amount of spinal motion presumably carries less risk than a larger amount, the accepted tenet in the field is thus regardless of what amount of spinal motion might induce clinically unfavorable outcomes, spinal motion should be minimized. As the threshold value is unknown, studies like ours investigate the order of motion by comparing different clinical techniques and look for ways to minimize spinal motion. With an unknown minimum clinically important difference, a *pre* hoc power calculation is not possible. By contrast, post hoc power calculations are generally strongly discouraged,[28,29] and were therefore not performed in this study. As a consequence of the above factors, the number of cadavers we included had to be determined by other means. Based on the group's experience in several previous studies,[18–24] it was decided that the number of cadavers used would be sufficient to demonstrate any existing differences. Still, several of the differences in our study had low but non-significant *P*-values (Table 1), and it cannot be ruled out that lack of statistical significance was due to limited statistical power.

We conclude that in unconscious trauma patients, the LTP or one of the two HAINES techniques is preferable to the standard recovery position in cases of an unstable cervical spine injury.

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Authors' Contribution

P. K. H.: Conceived of the lateral trauma position and the idea for the study.

M. B. H.: was a mentor and supervisor for PKH and oversaw the study itself.

B. P. C.: Engineered the adaption of the measuring equipment in the model.

P. K. H., M. B. H., B. P. C., D. N. D., M. P., and G. R. R.: Participated in the data acquisition.

J. R.: Devised and conducted the statistical analyses.

E. S.: Served as the head mentor and supervisor for PKH, including in the formulation of the study question and the manuscript draft.

All authors have contributed to the writing and revising of the manuscript.

The data acquisition was performed at the Center for Advanced Medical Learning & Simulation (CAMLS), University of South Florida, Tampa, FL, USA.

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